Relationship between Ferrel Cell Anomaly and Annular Mode

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1. Introduction

The relationship between Ferrel Cell anomaly (FCA) and Northern Hemisphere (NH) annular mode (NAM) has been investigated by Li and Wang (2003) based on a set of monthly data. The FCA may play an essential role in the formation of the NAM or Southern Hemisphere (SH) annular mode (SAM) through transporting air mass and result in the out-of-phase relationship of sea level pressure (SLP) anomalies between middle and high latitudes. In the light of the definitions of the NAM and SAM indices (Li and Wang, 2003; Nan and Li, 2003), recently, Li and Li (2009) have constructed daily NAM index (NAMI) and SAM index (SAMI), and found quasi-periodic (quasi-week and quasi-two-week) variability of annular mode (AM) in submonthly timescale. Here we employ a set of daily data to investigate the lead-lag relationship between the FCA and AM, and try to preliminarily interpret the quasi-periodic variability of AM in submonthly timescale.

3.Results

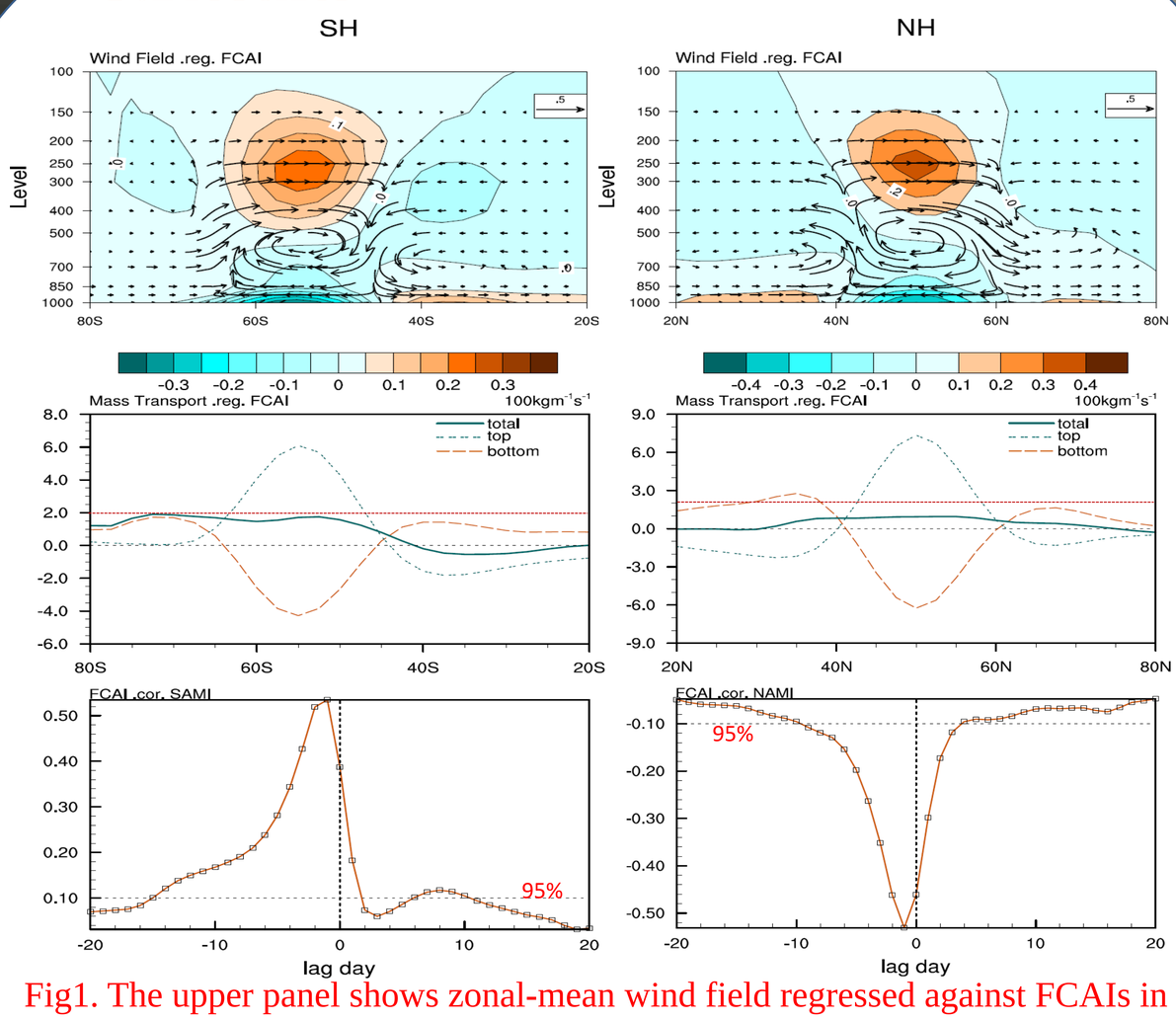
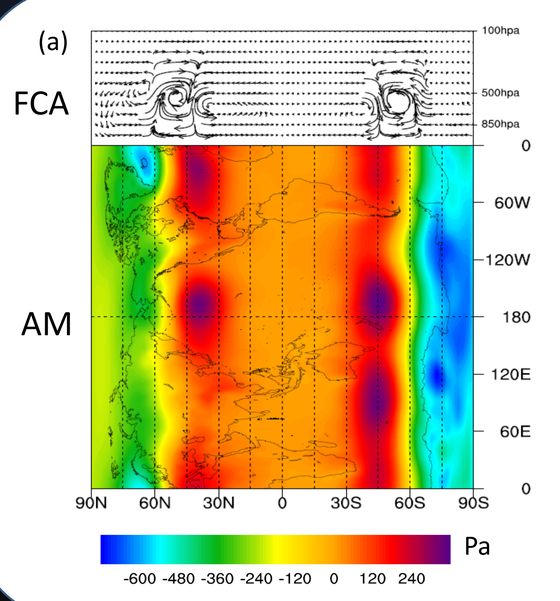


Fig1. The upper panel shows zonal-mean wind field regressed against FCAIs in both hemispheres, the zero-value level of meridional wind is 600hPa. The middle panel shows MT regressed against FCAIs in both hemispheres (total: integrating the whole levels (net MT); top: integrating the levels higher than 600hPa; bottom: integrating the levels lower than 600hPa). The lower panel shows the lead-lag correlation between FCAI and SAMI in SH and the lead-lag correlation between FCAI and NAMI in NH.



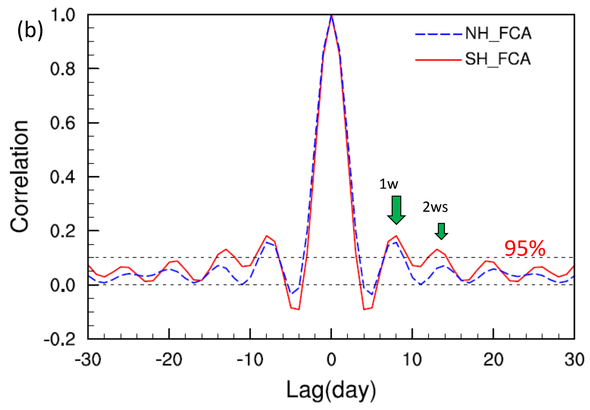


Fig2. (a) The spatial pattern of FCA and AM. (b) The autocorrelation of FCAIs (5-day low-pass filtered) in both hemispheres.

2. Data and methodology

The NCEP/NCAR reanalysis daily data (Kalnay et al. 1996) of 1979-2008 are employed here. The annual cycle has been removed from the raw data.

Indices:

1. Daily FCA index (FCAI). It is defined as the normalized area-average in daily zonal-mean zonal vorticity anomaly.

$$\frac{\partial[w]}{a\partial\varphi} - \frac{\partial[v]}{\partial z}$$

The variability of zonal-mean zonal vorticity (formula above) relies mainly on the vertical shear of meridional wind (blue) since the magnitude of meridional gradient of vertical velocity (red) (10^{-8} s^{-1}) is much smaller than the vertical shear of meridional wind (10^{-4} s^{-1}).

$$\left(\iint_{A_x} \frac{\partial[v]}{\partial z} dA_x\right) / A_x \qquad A_x \text{ represents the spatial region}$$

So we use the quantity (above) to calculate the FCAI. The spatial domains refer to the climatological mean positions of Fell Cell in both hemispheres (meridional direction: 50°S to 60°S in SH and 45°N to 55°N in NH; vertical direction: 700hPa to 300hPa).

2. NAMI and SAMI. The NAMI and SAMI are defined as follows (Li and Wang, 2003; Nan and Li, 2003; Li and Li, 2009):

$$NAMI = \hat{P}_{35^\circ N} - \hat{P}_{65^\circ N}$$

$$SAMI = \hat{P}_{40^\circ S} - \hat{P}_{70^\circ S}$$

$\hat{P}$: Normalized zonal-mean sea level pressure anomaly

After Zeng and Li (2002), the formula for calculating the mass transport (MT) is defined as follows:

$$MT = \frac{1}{g}\int_{p2}^{p1} v dp$$

Positive MT means mass transported from south to north.

Linear regression and correlation methods are employed.

4. Conclusions

The lead-lag relationship between FCA and AM is well represented based on a set of daily data. It appears that FCA induces AM by cross-latitude MT, and leads AM by one day. The MT induced by FCA in SH is larger than the MT in NH, which results in pronounced SAM. The FCAs in the two hemispheres both have quasi-week period and quasi-two-week period variability.

The zonal-mean meridional circulation may help us to understand the zonally symmetric pattern of atmosphere on the earth. Is there an universal law for the variability of meridional circulation on all planets? This is being studied in ongoing work.

References:

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